Multivibrators

* Non-linear circuits used to produce various signals like square or triangular waves.

Types of multivibrators

Bistable
⇒ Could be at one of two stable states indefinitely and only moves to the other state when it's appropriately triggered.

Monostable
⇒ Has one stable state.
⇒ Resides at the stable state in ordinary conditions, moves to the instable state when triggered for a specific interval then comes back to S.S.

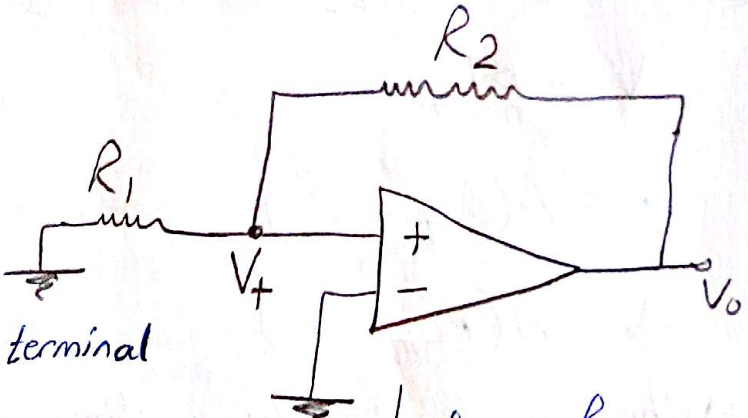
Astable
⇒ Doesn't have any stable state.
⇒ Stays at one of two levels for a period of time, then moves to the other level for another period and the process is repeated.
(Quasi-Stable states)

1 Bistable Multivibrators

* The feedback loop:

⇒ Large open-loop gain (A).

⇒ $V_+ = V_o \dfrac{R_1}{R_1+R_2} = \beta V_o$



$\beta = \dfrac{R_1}{R_1+R_2}$

$V_o = A(V_+ - V_-)$

⇒ Consider noise signal at V_+ terminal with small +ve value;
Noise amplified by the large gain (A).
∴ V_o increases with (+ve) value
∵ $V_+ = \beta V_o$ ⇒ ∴ $V_+ \rightarrow$ +ve value
When $A\beta > 1$ ⇒ V_+ is amplified again

V_o increases until it reaches the saturation level

$\therefore V_o = L_+$ (+ve saturation level)

$\rightarrow$ 1^{st} stable state

$\Rightarrow$ If noise signal is (−ve) value at the beginning:

$V_o = A(\underbrace{V_+}_{-ve} - \underbrace{V_-}_{0}) \rightarrow V_o$ is (−ve) & decreases

V_o continues to decreases till it reaches −ve saturation Level.

$V_o = L_-$

$\hookrightarrow$ 2^{nd} stable state.

$\Rightarrow$ Note that the circuit can't exist in the state for which ($V_+ = 0$ & $V_o = 0$) For any period of time.

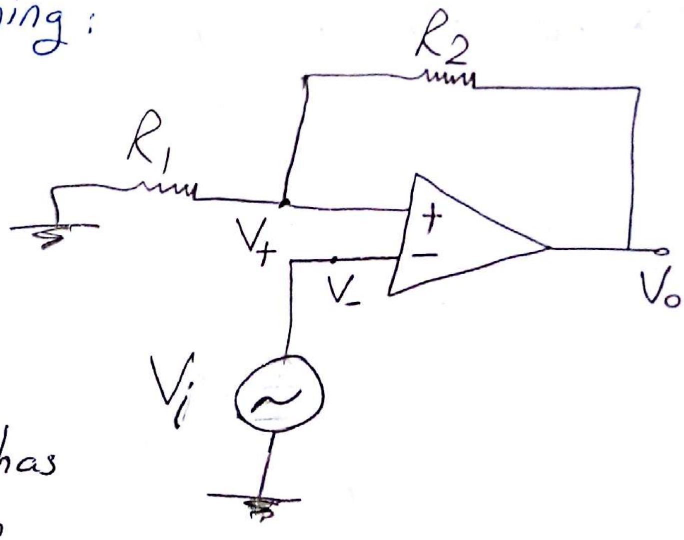
*Transfer Characteristics of inverting Bistable Multivibrator:

① Consider $V_o = L_+$ at the beginning:

$V_+ = \beta L_+$

$V_o = A(V_+ - V_-)$

$\therefore V_o = A(\beta L_+ - V_i)$



$\Rightarrow$ When V_i is firstly applied & has a small value, it'll have no effect on the output.

$\Rightarrow$ When $V_i = \beta L_+$ & begins to exceed this value: $V_o = A(\underbrace{\beta L_+ - V_i}_{-ve})$

$\therefore V_o$ becomes negative

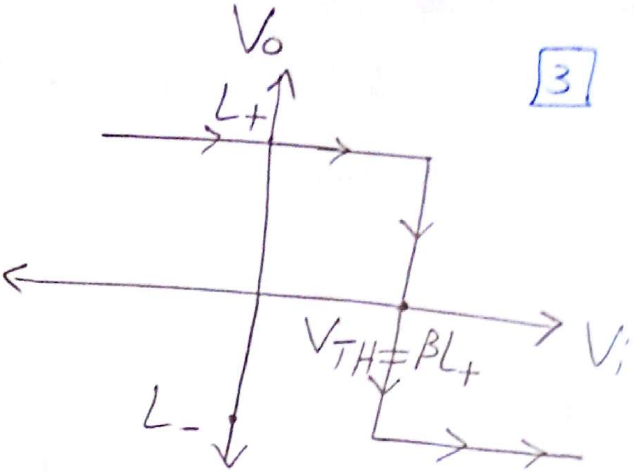
$V_o = L_-$ (other stable state)

$\Rightarrow$ At this point of transition:

$V_i = V_{TH}$

$\hookrightarrow$ High Threshold Voltage

$\therefore V_+ = \beta L_-$



② The case now is: $V_o = L_-$ & V_i will start to decrease

$V_+ = \beta L_-$ (-ve value)

$\Rightarrow$ If V_i increases, no effect on the output.

$\Rightarrow$ If V_i decreases until $V_i = \beta L_-$ & decreases more

$\therefore V_o = A(\underbrace{\beta L_- - V_i}_{+ve})$

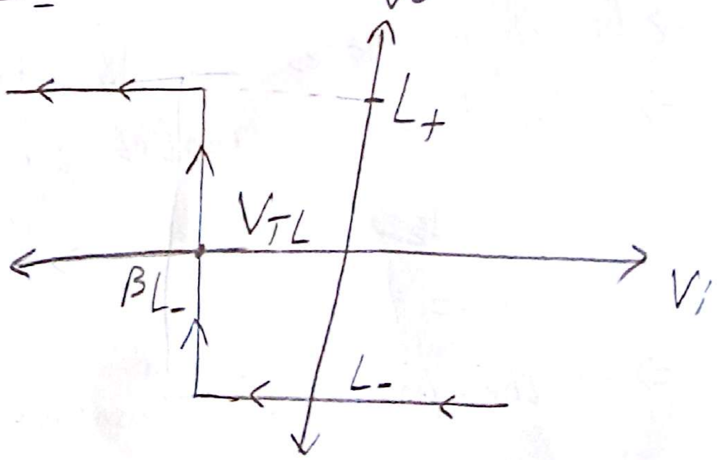
$\therefore V_o$ goes +ve again

$V_o = L_+$

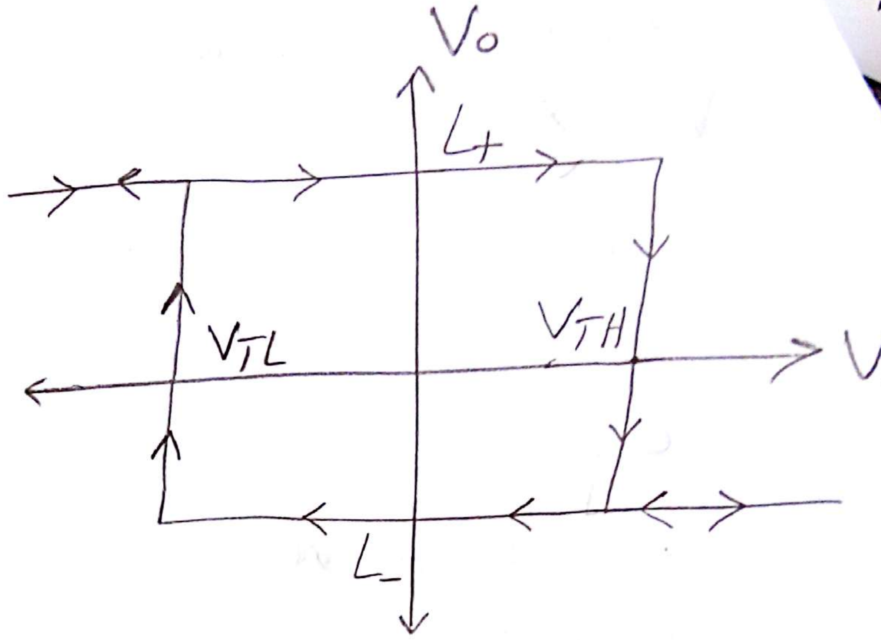
$V_+ = \beta L_+$

$\Rightarrow$ At this point of transition:

$V_i = V_{TL} = \beta L_-$



The total Ch/C can be drawn as follows:



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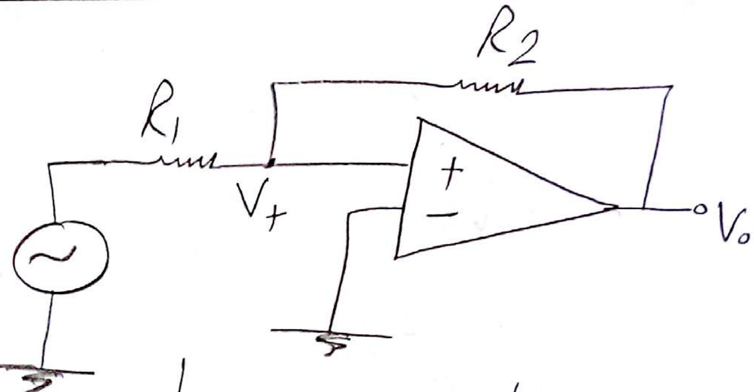
* Transfer Ch/C for non-inverting Bistable:

⇒ The voltage V_+ can be obtained using superposition:



$$V_+ = V_o \frac{R_1}{R_1+R_2} + V_i \frac{R_2}{R_1+R_2}$$

$$\boxed{\begin{gathered} V_o = A(V_+ - \underbrace{V_-}_{0}) \\ \therefore V_o = A V_+ \end{gathered}}$$

① Consider $V_o = L_+$ at the beginning:

$$V_+ = L_+ \frac{R_1}{R_1+R_2} + V_i \frac{R_2}{R_1+R_2}$$

⇒ If V_i increases ⇒ No effect

⇒ If V_i decreases until the total $V_+ = $ Zero

$\therefore V_o$ switches to the other state

$V_o = L_-$

⇒ At the point of transition: $V_+ = 0$

$$\therefore V_i \frac{R_2}{R_1+R_2} = -L_+ \frac{R_1}{R_1+R_2} \Rightarrow \therefore V_i = V_{TL} = -L_+ \frac{R_1}{R_2}$$

② Now $V_o = L_-$ & $V_+ = L_- \frac{R_1}{R_1+R_2} + V_i \frac{R_2}{R_1+R_2}$:

⇒ If V_i decreases → No effect.

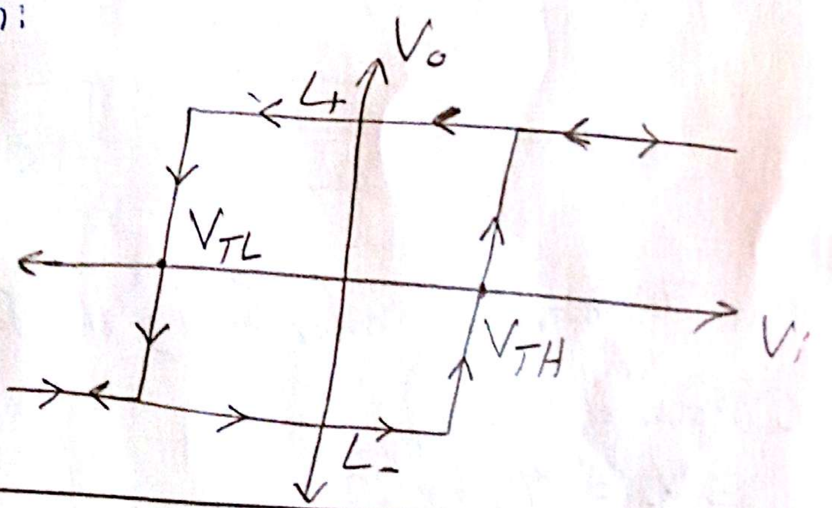
⇒ If V_i increases until $V_+ =$ Zero, V_o switches to the +ve saturation level.

: $V_o = L_+$

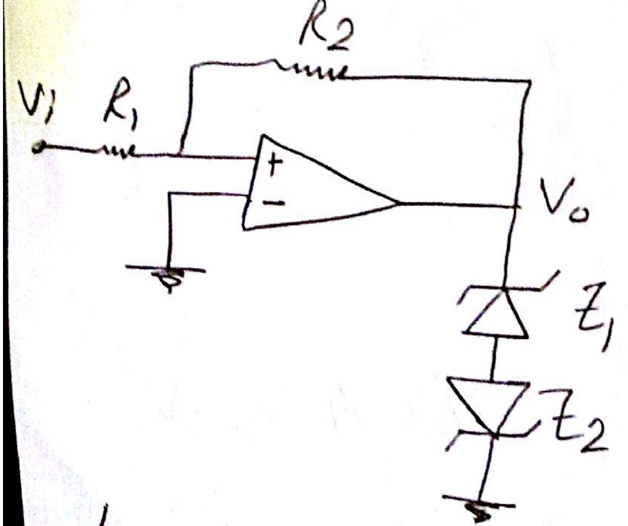
⇒ At this point of transition: $V_i \frac{R_2}{R_1+R_2} = -L_- \frac{R_1}{R_1+R_2}$

: $V_i = V_{TH} = -L_- \frac{R_1}{R_2}$

* The Ch/C can be drawn:

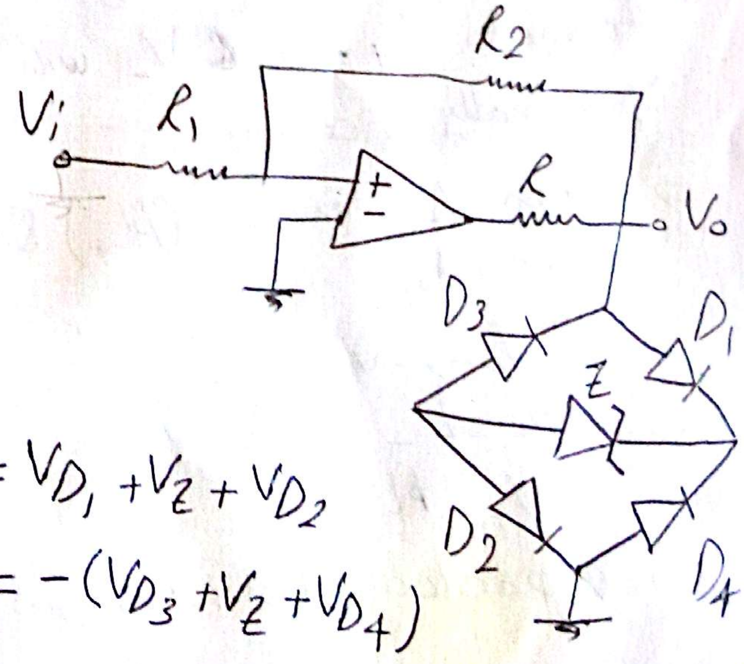


*Making the output level more precise:



$L_+ = V_{Z_1} + V_{D_2}$

$L_- = -(V_{D_1} + V_{Z_2})$

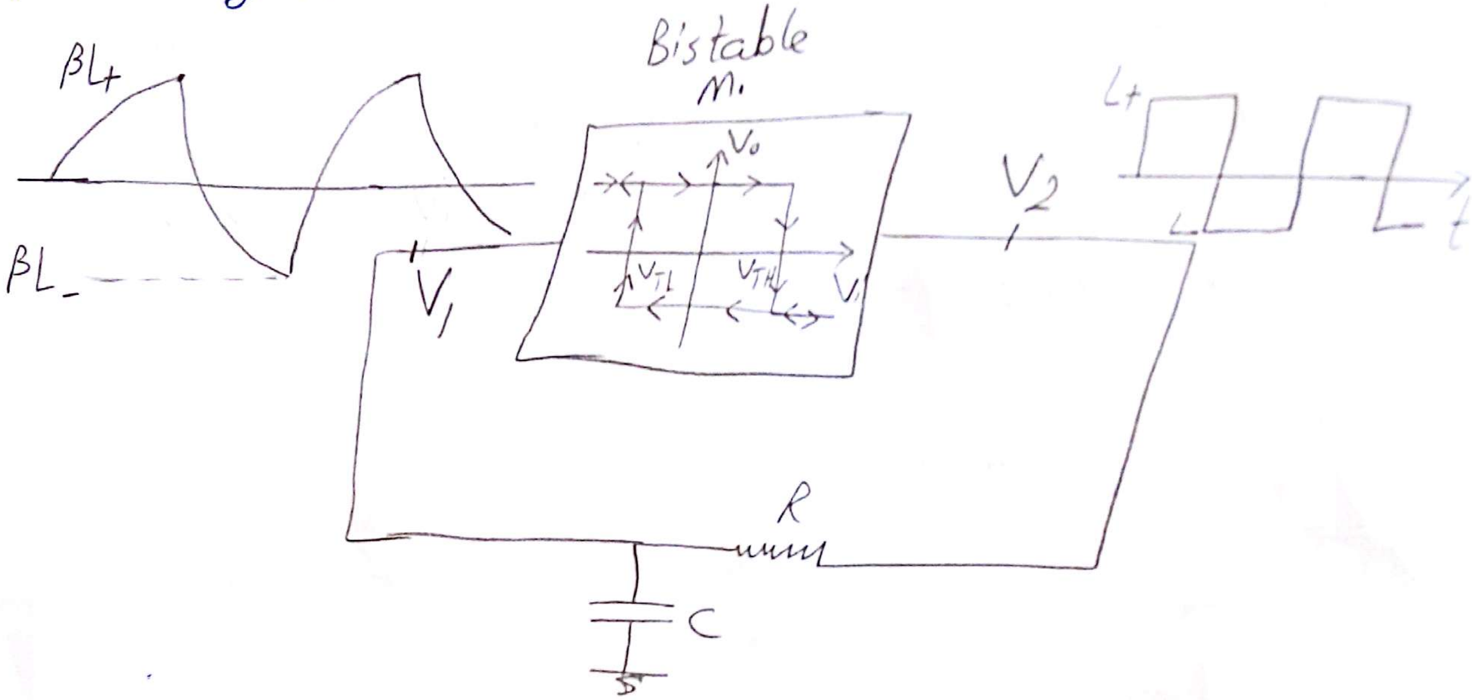


$L_+ = V_{D_1} + V_Z + V_{D_2}$

$L_- = -(V_{D_3} + V_Z + V_{D_4})$

[2] Astable MultiVibrators:-

* The bistable multivibrator can be arranged to switch periodically between the two states & become an astable M.



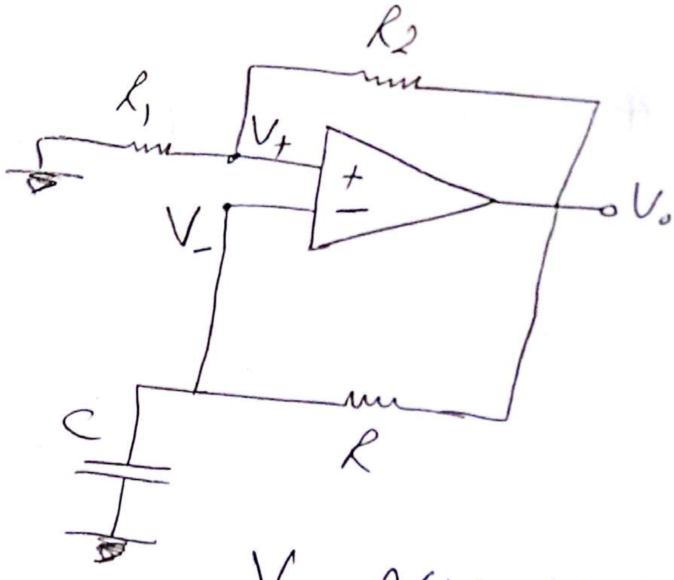
* This can be realized by the following circuit:

① Assume $V_o = L_+$:

$\Rightarrow V_+ = \beta L_+$

$\Rightarrow$ Capacitor C will charge towards L_+, so V_- will gradually increase.

$\Rightarrow$ When V_- reaches (βL_+) & exceeds.



$\therefore V_o \rightarrow -ve$

$V_o = L_-$

$\therefore V_+ = \beta L_-$

$$V_o = A(V_+ - V_-)$$

$\therefore$ Capacitor will discharge through R

$\therefore V_-$ gradually decreases until $V_- = \beta L_-$

$\Rightarrow$ When V_- decreases beyond (βL_-)

$\therefore V_0 \rightarrow +ve$

$V_0 = L_+$

Capacitor charges again.

* The time constant for Charging & discharging:

$\tau = RC$

$\Rightarrow$ The process is repeated periodically with a period $= T$

$T = T_1 + T_2$

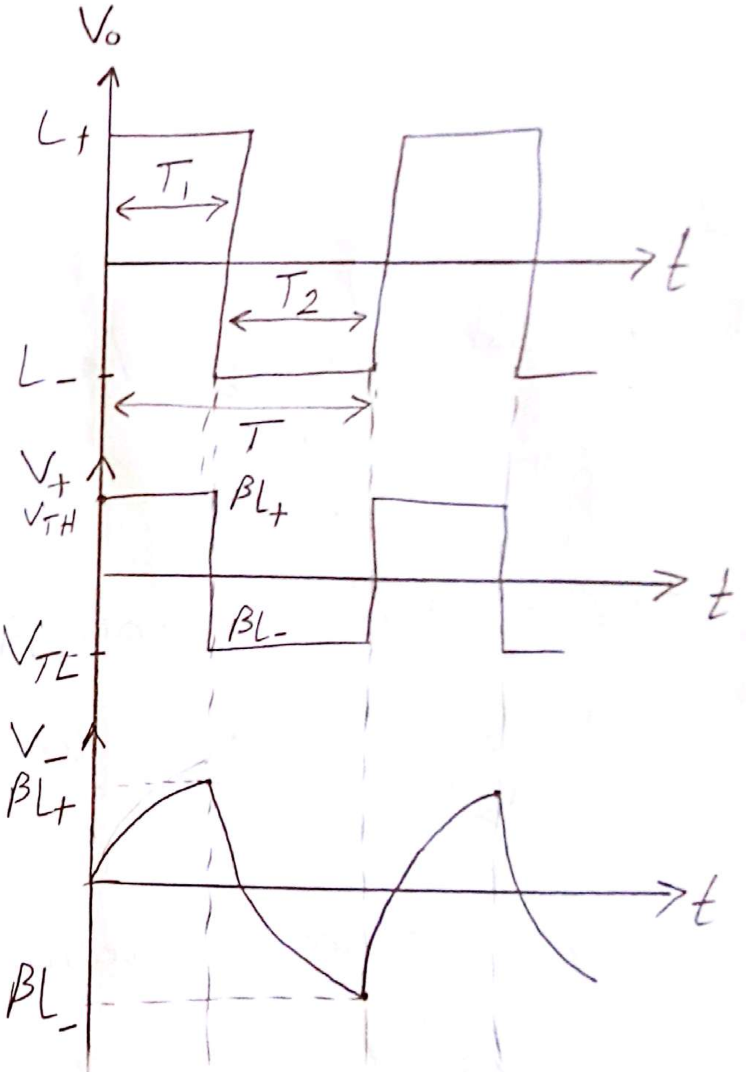
$$\Rightarrow T_1 = \tau \ln\left(\frac{1 - \beta\left[\frac{L_-}{L_+}\right]}{1 + \beta}\right)$$

$$\Rightarrow T_2 = \tau \ln\left(\frac{1 - \beta\left[\frac{L_+}{L_-}\right]}{1 - \beta}\right)$$

$\because L_+ = -L_-$

$\therefore T = T_1 + T_2$

$$\therefore T = 2\tau \ln\left(\frac{1+\beta}{1-\beta}\right)$$



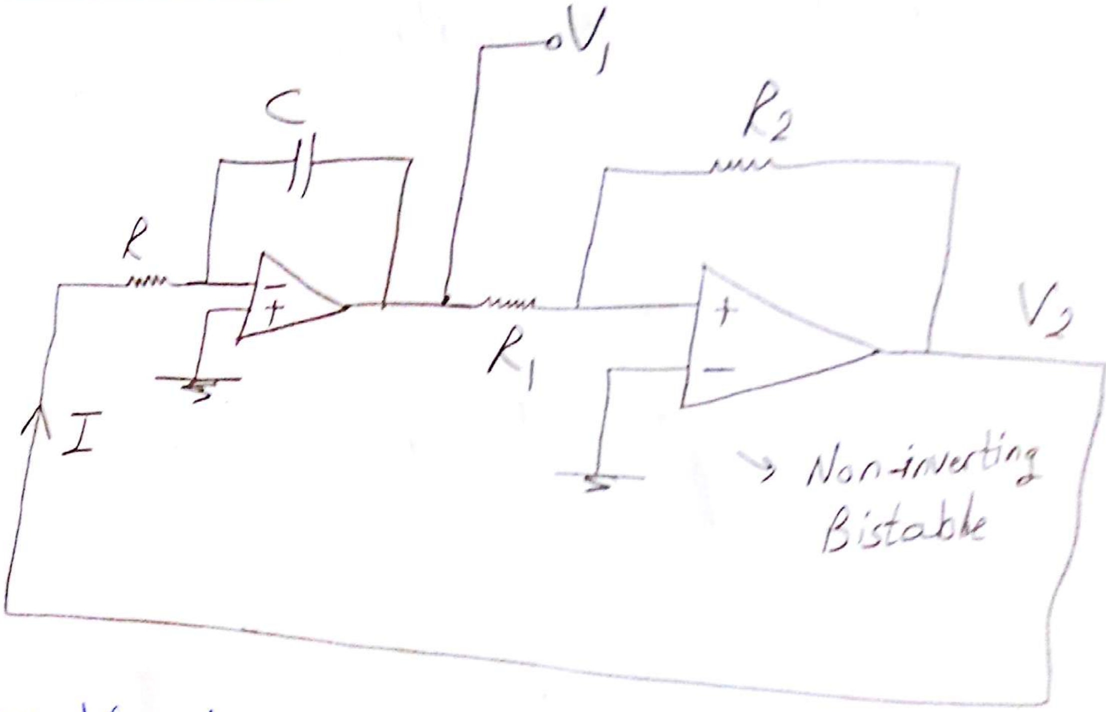
* $\boxed{\text{Note}}$: The general equation for the capacitor voltage when charging & discharging through R is:

$$v(t) = V_\infty - (V_\infty - V_{0+})e^{-t/\tau} \rightarrow RC$$

Final voltage (V_∞)

Voltage at $t=0+$ (the beginning) (V_{0+})

* Generation of triangular waveform :-



① Assume $V_2 = L_+$

⇒ The current passing through the capacitor will be:

$$I = \frac{L_+}{R}$$

⇒ O/P of the integrator decreases with a slope $= \frac{-L_+}{RC}$

⇒ O/P of integrator is the i/P for the multivibrator.
↳ V_1

⇒ V_1 continues to decrease untill $V_1 = V_{TL}$

$\therefore V_2 = L_-$

② $V_2 = L_-$ → (−ve value)

$\therefore V_1$ increases with a slope $= \frac{-L_-}{RC}$

V_1 continues to increase until $V_1 = V_{TH}$

$\therefore V_2 = L_+$

$$\Rightarrow T_1 = RC \, \frac{V_{TH} - V_{TL}}{L_+}$$

$$\Rightarrow T_2 = RC \, \frac{V_{TH} - V_{TL}}{L_-}$$

$$\Rightarrow V_{TH} = -L_- \frac{R_1}{R_2} \quad , V_{TL} = -L_+ \frac{R_1}{R_2}$$

$$L_+ = -L_-$$

$$\Rightarrow \therefore T = T_1 + T_2$$

$$T = 4RC \, \frac{R_1}{R_2}$$

$$\therefore f = \frac{1}{4RC} \, \frac{R_1}{R_2}$$